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(54) [Title of the Invention]

Method of Indicating Temperature Characteristic Codes of Electronic Parts, Temperature-Characteristic-Code-Bearing Electronic Parts and a Production System of Same Electronic Parts

(57) [Abstract]

[Problem] This invention relates to indication of temperature characteristic code of electronic parts typified by crystal resonators, for example, and relates to an improvement of an indication method to enable information about coefficients of an approximate equation to be recognized infallibly.

[Solution] A crystal resonator is excited in an atmosphere at 75℃, frequency deviations at this time are measured, measured values are put into codes, and those codes are decided to be first indication codes representing information about a linear coefficient a1. Second indication codes are obtained which represent a correlation between the linear coefficient a1 and a second order coefficient a2; a correlation between the linear coefficient a1 and a cubic coefficient a3; a correlation between the second order coefficient a2 and a fourth order coefficient a4; and a correlation between the cubic coefficient a3 and a fifth order coefficient a5. By placing a first indication code and a second indication code successively, a temperature characteristic code is formed and applied to the surface of the

crystal resonator.

[Claims]

[Claim 1]

A temperature characteristic code indication method for encoding information about a plurality of coefficients in an approximate equation representing changes of a characteristic of electronic parts against the environmental temperature, and indicating a temperature characteristic code, comprising:

a first-indication-code deciding process for measuring a characteristic value changing with changes in the environmental temperature under a predetermined environmental temperature and, based on measurement results, deciding information about a specific coefficient out of said plurality of coefficients to be the first indication code; and

a second-indication-code deciding process for deciding correlations between at least said specific coefficient and other coefficients to be a second indication code,

wherein a temperature characteristic code is formed by combining the first indication code and the second indication code decided in said respective processes and said temperature characteristic code is applied to the surface of electronic parts.

[Claim 2]

The temperature characteristic code indication method for electronic parts according to Claim 1, wherein the second indication code is a code formed by associating correlations between a specific coefficient and other coefficients with correlations between a plurality of coefficients other than said specific coefficient.

[Claim 3]

The temperature characteristic code indication method for electronic parts according to Claim 2, wherein in said second indication method is, in addition to setting a plurality of candidates for correlations between a specific coefficient and other coefficients, a plurality of candidates for correlations between a plurality of coefficients other than said specific coefficient are also set, and an indication code is allocated to each of those candidates, and out of those candidates, an indication code allocated to a candidate capable of obtaining an approximate equation with highest approximation accuracy is decided to be the second indication code.

[Claim 4]

The temperature characteristic code indication method for electronic parts according to Claim 1, 2 or 3, wherein a two-dimensional data code having a combination of many dots to show information about a plurality of coefficients in an approximate equation is written on the surface of each

electronic part together with a temperature characteristic code including the first and second indication codes.

[Claim 5]

The temperature characteristic code indication method for electronic parts according to one of Claims 1 to 4, wherein said electronic part is a crystal resonator, and wherein a temperature characteristic code is formed and applied by combining information about a plurality of coefficients of an approximate equation representing a crystal resonator's frequency characteristic changing with changes of the environmental temperature.

[Claim 6]

Electronic parts bearing temperature characteristic codes by a temperature characteristic code indication method according to one of Claims 1 to 5.

[Claim 7]

A production system of electronic parts with a temperature characteristic code indicated by the temperature characteristic code indication method according to Claim 4, said production system comprising:

a code reading means capable of reading a two-dimensional data code;

a decision means for deciding whether or not a two-dimensional data code could be read satisfactorily or not

by said code reading means; and

a part discrimination means for transferring an electronic part to a subsequent process of the production line when, on receiving output of said decision means, a two-dimensional data code could be read satisfactorily, and ejecting said electronic part to an indication code recognition station for recognizing the first and second indication codes when the two-dimensional data code could not be read satisfactorily.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a method for indicating a temperature characteristic code of electronic parts typified by crystal resonators, for example, and also relates to temperature-characteristic-code bearing electronic parts and a production system of those electronic parts. More particularly, the present invention relates to a means to make it possible to securely recognize information about a plurality of coefficients in an approximate equation representing the temperature characteristic.

[0002]

[Prior Art]

Up till now, in a digital temperature compensated crystal oscillator disclosed in Patent Application Laid-Open No.

9-55624, for example, it is required that output frequency is kept constant regardless of changes in the atmospheric temperature (environmental temperature). However, in an AT-cut crystal resonator, for example, as shown in Fig. 10 (a graph showing the relation of deviations of oscillation frequency from the reference frequency against temperature), the changes of oscillation frequency against temperature has a characteristic takes a form like a cubic one. Therefore, the above-mentioned crystal oscillator includes a temperature compensation circuit, which includes a memory storing data corresponding to the temperature characteristic of the crystal resonator to keep the output frequency constant even though the temperature changes.

[0003]

Data for this temperature compensation is prepared based on an approximate equation in a cubic curve. Meanwhile, with the increase in the accuracy of crystal oscillators in recent years, high approximation accuracy close to this approximate equation has been required. As means to meet this requirement, the use of higher order approximation (fifth order approximation, for example) may be considered promising. For example, an approximate equation of fifth order approximation when the reference temperature is 25℃, for example, is expressed as follows.

[0004]

$$\Delta f = a1(T-25) + a^2(T-25)^2 + a3(T-25)^3 + a4(T-25)^4 + a5(T-25)^5 \quad \text{..........} \quad (1)$$

where Δf: frequency deviation, a1~a5: coefficients of respective orders, T: environmental temperature

By obtaining the coefficients of a1 to a5 in an approximate equation (1) from measured values of the crystal resonator, an approximate equation is obtained, and from this approximate equation, data for temperature compensation is prepared.

[0005]

On an actual production line of crystal resonators, it is arranged that an approximate equation can be obtained by reading information about the above-mentioned coefficients a1 to a5 indicated on crystal resonators (on cap surface, for example).

[0006]

In indication of information about the coefficients a1 to a5, a relatively large number of digits are required to avoid the occurrence of errors by cancellation of significant digits, and even if exponential notation is used, about four digits are required for each coefficient. Therefore, when all coefficients are to be indicated, it is necessary to previously make an arrangement to indicate a relatively large amount of information of about 20 digits, which include signs for the coefficients. To indicate such a relatively large amount of

information on a small crystal resonator, an indication method by a so-called two-dimensional data code made up of a large number of dots has been generally adopted. This indication method is such that a specified area on a crystal resonator is set as an indication area for information about each coefficient and in that area, a number of dots (minute dents) are formed with a laser, the dot-formed positions are set associated with information about each coefficient, and by reading the dot-formed positions with a camera, information about each coefficient is obtained from camera-read data. A information indication method by dots is disclosed in Japanese Patent Publication No. 8-21-054, for example. There is another indication method in which, for example, a tape having dots applied to its top surface with a proper means and the rear surface coated with sticky material is attached to a crystal resonator.

[0007]

[Problem to be solved by the Invention]

However, if it is arranged for information about each coefficient to be obtained from two-dimensional data code as described above, there is a possibility that information cannot be read accurately depending on the recognition accuracy of the camera. If there are scars on the two-dimensional data code indication area, the dot-formed positions may not be recognized

accurately, or, furthermore, due to effects of the surface-processed state (surface roughness, gloss, etc.) of the two-dimensional data code indication area, the dot-formed positions may not be recognized correctly.

[0008]

As stated above, with crystal resonators on which the dot-formed positions cannot be recognized, the information about each coefficient cannot be obtained, in other words, an approximate equation information about a cubic curve cannot be acquired, it is impossible to create data for temperature compensation. Therefore, under existing circumstances, such crystal resonators have to be scrapped because there is no better alternative, which is one of the factors causing a considerable aggravation of the yield ratio of the temperature compensation crystal oscillators.

[0009]

The present invention has been made the above problems in mind and has as its object to make it possible to securely recognize information about the coefficients of an approximate equation by an improvement made to the indication method of temperature characteristic codes of electronic parts, represented by crystal resonators.

[0010]

[Means for solving the Problem]

- Summary of the Invention -

To achieve the above object, the present invention makes it possible to unfailingly recognize information about each coefficient by adopting a code recognizable by the operator as information about a plurality of coefficients in an approximate equation. With regard to the code, by combining an indication code portion representing coefficient information based on measured values and an indication code portion representing a correlation of an coefficient and another coefficient, it becomes possible to adopt a higher order number in approximation while limiting the number of digits of a code.

[0011]

- Means of Solution -

More specifically, a first solving means is aimed at a temperature characteristic code indication method which includes encoding and indicating information about a plurality of coefficients in an approximate equation representing changes of the characteristic of electronic parts against temperature. A temperature characteristic code indication method comprises a first-indication-code deciding process for measuring the characteristic value that changes with changes under predetermined environmental temperature and, based on measurement results, deciding information about a specific coefficient out of the plurality of coefficients as the first

indication code; and a second indication code deciding process for deciding correlations between at least the specific coefficient and other coefficients as second indication codes, wherein a temperature characteristic code is formed by combining the first indication code and the second indication code decided in the respective processes and applied to the surfaces of electronic parts.

[0012]

For example, as indication codes, combinations of numerals and alphabetical letters, for example, are adopted. Therefore, codes recognizable to the workers can be realized, a plurality of coefficients in an approximate equation can be obtained easily, and approximate equation information can be acquired securely.

[0013]

A second solving means is, in the above-mentioned first solving means, to form the second indication code by associating correlations between a specific coefficient and other coefficients with correlations between a plurality of coefficients other than the specific coefficient.

[0014]

According to the above feature, when a high order approximate equation, such as a fifth order approximation, is adopted, it is possible to use code indication without

increasing the number of digits of code and information that can be obtained with high approximation accuracy can be indicated in a relatively small indication area.

[0015]

A third solving means is, in the second solving means, in addition to setting a plurality of candidates for correlations between a specific coefficient and other coefficients, a plurality of candidates for correlations between a plurality of coefficients other than the specific coefficient are also set, an indication code is allocated to each of those candidates, and out of those candidates, an indication code allocated to a candidate capable of obtaining an approximate equation with highest approximation accuracy is decided to be the second indication code.

[0016]

According to the above feature, even if an error occurred when obtaining correlations between coefficients, because a plurality of correlation candidates are set and a candidate with highest reliability is selected, it is possible to obtain correlations between coefficients which are hardly susceptible to effects of the above-mentioned error, and therefore it is possible to further improve the approximation accuracy.

[0017]

A fourth solving means is, in the above-mentioned first,

second or third solving means, a two-dimensional data code having a combination of many dots to show information about a plurality of coefficients in an approximate equation is written on the surface of each electronic part together with a temperature characteristic code including the first and second indication codes.

[0018]

According to the above feature, while it is made possible to recognize the coefficients by taking a picture in a conventional manner by using an image-pickup means, such as a camera, of two-dimensional data codes, it is also possible to obtain the effects of the above-mentioned problem-solving means. In other words, even when a two-dimensional data code could not be read by the above-mentioned image pickup means, it is possible to obtain information about the coefficients by visually checking the temperature characteristic code.

[0019]

A fifth solving means is, in one of the above-mentioned solving means 1 to 4, the electronic part is a crystal resonator, and a temperature characteristic code is formed and applied by combining information about a plurality of coefficients of an approximate equation representing a crystal resonator's frequency characteristic changing with changes of the environmental temperature.

[0020]

According to the above feature, it is possible to indicate a high-reliability temperature characteristic code on crystal resonators which are required to have a very high approximation accuracy.

[0021]

A sixth solving means relates to electronic parts carrying a temperature characteristic code according to the above-mentioned temperature characteristic code indication method. In the case of conventional electronic parts having only a two-dimensional data code, if this two-dimensional data code could not be read by the camera, no other means to obtain coefficient information is available for that electronic part and the electronic part has to be disposed of. With electronic parts related to this solving means, because information about each coefficient can be obtained by visually checking the temperature characteristic code, it has become unnecessary to discard the electronic part and it is possible improve the yield rate.

[0022]

A seventh solving means relates to a production system of electronic parts having a temperature characteristic code by a temperature characteristic code indication method according to the above-mentioned fourth solving means. The production

system comprises a code reading means capable of reading a two-dimensional data code; a decision means for deciding whether or not a two-dimensional data code could be read satisfactorily by the code reading means; and a part discrimination means for transferring an electronic part to a subsequent process of the production line when, on receiving output of the decision means, a two-dimensional data code could be read satisfactorily, and ejecting the electronic part to an indication code recognition station for recognizing the first and second indication codes when the two-dimensional data code could not be read satisfactorily.

[0023]

According to this feature, even when acquisition of information about each coefficient by reading a two-dimensional data code was unsuccessful, it is possible to visually recognize the temperature characteristic code on electronic parts at the indication code recognition station. As mentioned above, by the simultaneous use of reading of a two-dimensional data code and visual recognition of a temperature characteristic code, it has become possible to obtain coefficient information about substantially all electronic parts.

[0024]

[Mode for Carrying out the Invention]

A mode for carrying out the present invention will be

described with reference to the accompanying drawings. Before describing a temperature characteristic code indication method according to the present invention, description will first be made of the outline of an ordinary digital temperature-compensated crystal oscillator.

[0025]

Fig. 1 is a block diagram showing a circuit configuration of a digital temperature-compensated crystal oscillator 1. As shown in Fig. 1, the crystal oscillator 1 of this kind includes a temperature detecting circuit 11, a temperature compensation voltage generating circuit 12, a constant voltage generating circuit 13, a programmable gain amplifier 14, an adder circuit 15, and a voltage-controlled crystal oscillation circuit (VCXO) 16.

[0026]

The temperature detecting circuit 11 outputs an analog voltage which changes like a linear function in accordance with changes in the environmental temperature. A temperature detected value in the form of an analog voltage output from the temperature detecting circuit 11 is supplied to the temperature compensation voltage generating circuit 12 for generating an analog output voltage in an approximation cubic curve corresponding to a temperature characteristic of the crystal resonator based on the temperature detected value. The

constant voltage generating circuit 13 generates a constant voltage at a fixed level regardless of temperature changes.

[0027]

On one hand, an analog voltage of the constant voltage generating circuit 13 is passed through the programmable gain amplifier 14 and input to the adder circuit 15 as a control signal generating circuit, and on the other hand, a temperature detected value in the form of an analog output voltage from the temperature compensation voltage generating circuit 12 is also input to the adder circuit 15. An addition output of the adder circuit 15 is input to the voltage-controlled crystal oscillation circuit 16 as a control voltage to maintain an output frequency from the voltage-controlled crystal oscillation circuit 16 at a fixed value regardless of the environmental temperature. Meanwhile, the crystal resonator is included in an oscillation circuit configured in the voltage-controlled crystal oscillation circuit 16. The structural outline of the digital temperature-compensated crystal oscillator has been decribed.

[0028]

- Temperature Characteristic Code Indication Method -

Description will be made of a temperature characteristic code indication method for encoding and indicating information about a plurality of coefficients of an approximate equation

representing a temperature characteristic of a crystal resonator. Description starts with a case where the order number of approximation is the fifth order. In other words, description will be made a case where there are five coefficients a1 to a5 in an approximate equation to represent changes of a temperature characteristic (Refer to equation (1) mentioned above).

[0029]

With regard to the procedure of the temperature characteristic code indication method in this mode of embodiment, a first-indication-code deciding process to obtain a first indication code, a second indication code deciding process to obtain a second indication code, and an indication process to combine indication codes obtained in these processes to indicate as a temperature characteristic code on the surface (cap surface) of a crystal resonator are carried out in this order.

[0030]

(First-indication-code deciding Process)

Description is made of the first-indication-code deciding process for measuring the oscillation frequency (characteristic value in this invention) of a crystal resonator, which changes with changes of the environmental temperature under specified environmental temperatures and, based on

measurement results, deciding information about the above-mentioned coefficient a1 (a specific coefficient in this invention) to be the first indication code.

[0031]

To be more specific, this first-indication-code deciding process is performed such that a manufactured crystal resonator is made to excite in an atmosphere at 75℃, and deviations of oscillation frequency from a reference frequency (frequency deviations) at this time are measured.

[0032]

Fig. 2 is a graph showing a correlation between frequency deviations (Δf) and the linear coefficient a1 when a plurality of crystal resonators are excited in the atmosphere at 75℃. As shown in this graph, there is a substantially definite correlation between frequency deviations and the linear coefficient a1, and if frequency deviations at a certain temperature (75℃ in this case) are obtained, the linear coefficient a1 is decided uniquely. Therefore, in this process, frequency deviation values at the above-mentioned predetermined temperature (75℃) are measured, and the measured frequency deviation values are expressed in codes and the first indication codes as information about the linear coefficient a1 are decided.

[0033]

Table 1 shows the relation between frequency deviations Δf in the case described above and the first indication codes decided by frequency deviations.

[0034]

[Table 1]

CODE	75°C Δf(ppm)	CODE	75°C Δf(ppm)	CODE	75°C Δf(ppm)	CODE	75°C Δf(ppm)	CODE	75°C Δf(ppm)
0A	10.0	2C	6.0	4E	2.0	6G	-2.0	8J	-6.0
0B	9.9	2D	5.9	4F	1.9	6H	-2.1	8K	-6.1
0C	9.8	2E	5.8	4G	1.8	6J	-2.2	8L	-6.2
0D	9.7	2F	5.7	4H	1.7	6K	-2.3	8M	-6.3
0E	9.6	2G	5.6	4J	1.6	6L	-2.4	8N	-6.4
0F	9.5	2H	5.5	4K	1.5	6M	-2.5	8P	-6.5
0G	9.4	2J	5.4	4L	1.4	6N	-2.6	8R	-6.6
0H	9.3	2K	5.3	4M	1.3	6P	-2.7	8T	-6.7
0J	9.2	2L	5.2	4N	1.2	6R	-2.8	8W	-6.8
0K	9.1	2M	5.1	4P	1.1	6T	-2.9	8X	-6.9
0L	9.0	2N	5.0	4R	1.0	6W	-3.0	8Y	-7.0
0M	8.9	2P	4.9	4T	0.9	6X	-3.1	9A	-7.1
0N	8.8	2R	4.8	4W	0.8	6Y	-3.2	9B	-7.2
0P	8.7	2T	4.7	4X	0.7	7A	-3.3	9C	-7.3
0R	8.6	2W	4.6	4Y	0.6	7B	-3.4	9D	-7.4
0T	8.5	2X	4.5	5A	0.5	7C	-3.5	9E	-7.5
0W	8.4	2Y	4.4	5B	0.4	7D	-3.6	9F	-7.6
0X	8.3	3A	4.3	5C	0.3	7E	-3.7	9G	-7.7
0Y	8.2	3B	4.2	5D	0.2	7F	-3.8	9H	-7.8
1A	8.1	3C	4.1	5E	0.1	7G	-3.9	9J	-7.9
1B	8.0	3D	4.0	5F	0.0	7H	-4.0	9K	-8.0
1C	7.9	3E	3.9	5G	-0.1	7J	-4.1	9L	-8.1
1D	7.8	3F	3.8	5H	-0.2	7K	-4.2	9M	-8.2
1E	7.7	3G	3.7	5J	-0.3	7L	-4.3	9N	-8.3
1F	7.6	3H	3.6	5K	-0.4	7M	-4.4	9P	-8.4
1G	7.5	3J	3.5	5L	-0.5	7N	-4.5	9R	-8.5
1H	7.4	3K	3.4	5M	-0.6	7P	-4.6	9T	-8.6
1J	7.3	3L	3.3	5N	-0.7	7R	-4.7	9W	-8.7
1K	7.2	3M	3.2	5P	-0.8	7T	-4.8	9X	-8.8
1L	7.1	3N	3.1	5R	-0.9	7W	-4.9	9Y	-8.9
1M	7.0	3P	3.0	5T	-1.0	7X	-5.0	AA	-9.0
1N	6.9	3R	2.9	5W	-1.1	7Y	-5.1	AB	-9.1
1P	6.8	3T	2.8	5X	-1.2	8A	-5.2	AC	-9.2
1R	6.7	3W	2.7	5Y	-1.3	8B	-5.3	AD	-9.3
1T	6.6	3X	2.6	6A	-1.4	8C	-5.4	AE	-9.4
1W	6.5	3Y	2.5	6B	-1.5	8D	-5.5	AF	-9.5
1X	6.4	4A	2.4	6C	-1.6	8E	-5.6	AG	-9.6
1Y	6.3	4B	2.3	6D	-1.7	8F	-5.7	AH	-9.7
2A	6.2	4C	2.2	6E	-1.8	8G	-5.8	AJ	-9.8
2B	6.1	4D	2.1	6F	-1.9	8H	-5.9	AK	-9.9
								AL	-10.0

[0035]

In this Table, a range of frequency deviations is set with 10.0ppm as the upper limit and -10.0ppm as the lower limit, and codes of two letters (two digits or two letters of one digit and one alphabetical letter or two alphabetical letters) are allocated to every 0.1ppm. For example, in an atmospheric air at 75℃, if a frequency deviation is 0.0, its indication code is "5F", and if a frequency deviation is 2.0, its indication code is "4E". From a first indication code, the value of the linear coefficient a1 can be known. In other words, according to Fig. 2, if the code is "5F(a frequency deviation is 0.0)", the linear coefficient a1 is "-16E-4", and if the code is "4E(a frequency deviation is 2.0)", the coefficient a1 can be known to be "-122E-3". Therefore, in a case where a correlation is as shown Fig. 2, a relational equation (2) holds between frequency deviations and the coefficient a1.

$$V = 0.019 \times (\text{frequency deviation at } 75℃ : \Delta f) - 0.16 \ldots (2)$$

Where V is a value of the linear coefficient a1.

[0037]

(Second Indication Code Deciding Process)

Description will next be made of a second indication code deciding process for deciding correlations between the linear coefficient a1 and other coefficients and coefficients between coefficients other than the linear coefficient a1 to be second

indication codes. More specifically, in the second indication deciding process, second indication codes are obtained as indication codes to represent a correlation between the linear coefficient a1 and the second order coefficient a2, a correlation between the linear coefficient a1 and the cubic coefficient a3, a correlation between the second order coefficient a2 and the fourth order coefficient 4a, and a correlation between the cubic coefficient a3 and the fifth order coefficient a5.

[0038]

Figs. 3 to 6 are graphs showing correlations between the coefficients of an approximate equation, which are obtained from measured values of oscillation frequencies of a plurality of crystal resonators. Fig. 3 is a graph showing a correlation between the linear coefficient a1 and the second order coefficient a2, Fig. 4 is a graph showing a correlation between the linear coefficient a1 and the cubic coefficient a3, Fig. 5 is a graph showing a correlation between the second order coefficient a2 and the fourth order coefficient a4, and Fig. 6 is a graph showing a correlation between the cubic coefficient a3 and the fifth order coefficient a5. As these graphs show, there are correlations between different order-number coefficients, and from those correlations, the second indication codes are determined. Meanwhile, in Figs. 3 to 6,

a straight line B passes almost the medians of data, and straight lines A and C cover the areas formed by these straight lines drawn by up and down translation of the above-mentioned medians constituting the straight line B for a predetermined width in each direction to compensate measurement errors.

[0039]

If equations representing correlations between coefficients are to be sought with those straight lines taken into account, relational equations representing a plurality of candidates for correlations are found as follows.

[0040]

<Correlation equations between linear and second order coefficients a1 and a2>

W0 = 1.0E-3×V-1.57E-3 .... (3)

W1 = 1.0E-3×V-1.51E-3 .... (4)

W2 = 1.0E-3×V-1.63E-3 .... (5)

where W0 is values of the second order coefficient a2 on the straight line B in Fig. 3, W1 is values of the second order coefficient a2 on the straight line A in Fig. 3, and W3 is values of the second order coefficient a2 on the straight line C in Fig. 3.

[0041]

For a correlation between the linear coefficient a1 and the second order coefficient a2, three candidates can be

obtained by using the straight lines A, B and C with measurement errors taken into account. Out of those candidates, a candidate with highest approximation accuracy can be selected by a selection operation which will be described later. (This equally applies to correlation equations between coefficients.)

[0042]

<Correlation equations between the linear and cubic coefficients a1 and a3>

$$X0 = -1.9E-4 \times V-2.5E-7 \;\ldots\ldots\; (6)$$

$$X1 = -1.9E-4 \times V-1.4E-7 \;\ldots\ldots\; (7)$$

$$X2 = -1.9E-4 \times X-2.6E-7 \;\ldots\ldots\; (8)$$

where X0 is values of the cubic coefficient a3 on the straight line B in Fig. 4, X1 is values of the cubic coefficient a3 on the straight line A in Fig. 4, and X2 is values of the cubic coefficient a3 on the straight line C in Fig. 4.

[0043]

<Correlation equations between the second order coefficient a2 and the fourth order coefficient a4>

$$Y0 = -1.7E-6 \times W0+9.41E-5 \;\ldots\ldots\; (9)$$

$$Y1 = -1.7E-6 \times W0+9.56E-5 \;\ldots\ldots\; (10)$$

$$Y2 = -1.7E-6 \times W0+9.26E-5 \;\ldots\ldots\; (11)$$

[0044]

<Correlation equations between the cubic coefficient a3 and the

fifth order coefficient a5>

$$Z0 = -1.9E-4 \times X0 + 1.82E-8 \quad \ldots\ldots\ldots \quad (12)$$

$$Z1 = -1.9E-4 \times X0 + 1.84E-8 \quad \ldots\ldots\ldots \quad (13)$$

$$Z2 = -1.9E-4 \times X0 + 1.81E-8 \quad \ldots\ldots\ldots \quad (14)$$

where Z0 is values of the fifth order coefficient a5 on the straight line B in Fig. 6, Z1 is values of the fifth order coefficient a5 on the straight line A in Fig. 6, and Z2 is values the fifth order coefficient a5 on the straight line C in Fig. 6.

[0045]

For a correlation between coefficients, a plurality of candidates can be obtained. Combinations of the candidates (17 combinations in this embodiment) are shown in Table 2. Indication codes "A" to "W" are allocated to the candidates.

[0046]

[Table 2]

CODE	LINEAR COEFF.	SECOND ORDER COEFF.	CUBIC COEFF.	FOURTH ORDER COEFF.	FIFTH ORDER COEFF.
A	V	W0	X0	Y0	Z0
B	〃	W1	X1	Y1	Z1
C	〃	〃	〃	〃	Z2
D	〃	〃	〃	Y2	Z1
E	〃	〃	〃	〃	Z2
F	〃	〃	X2	Y1	Z1
G	〃	〃	〃	〃	Z2
H	〃	〃	〃	Y2	Z1
J	〃	〃	〃	〃	Z2
K	〃	W2	X1	Y1	Z1
L	〃	〃	〃	〃	Z2
M	〃	〃	〃	Y2	Z1
N	〃	〃	〃	〃	Z2
P	〃	〃	X2	Y1	Z1
R	〃	〃	〃	〃	Z2
T	〃	〃	〃	Y2	Z1
W	〃	〃	〃	〃	Z2

[0047]

Out of those candidates, a combination with highest approximation accuracy is selected, the indication code allocated to the selected candidate is decided to be the second indication code. In other words, if approximated curves are obtained by correlation between 17 candidates, as shown in Fig. 7, mutually different approximated curves, particularly, a plurality of patterns of approximated curves can be obtained which have different frequency deviations between the high temperature range and the low temperature range. The second indication codes are decided (selected) which represent correlations between coefficients, which make it possible to obtain an approximated curve with high approximation accuracy most in consonance with measured values out of those approximated curves. The decision operation of second indication codes is described in the following.

[0048]

On the crystal resonator to which the indication code is applied, the frequency deviations under a plurality of environmental temperature are measured. More specifically, frequency deviations are measured under temperature of 75℃, 60℃, 45℃, 25℃, 5℃, -15℃, and -20℃. For each of the candidates, frequency deviations are calculated under the same temperature conditions as mentioned above. Table 3 shows the measurement

and calculation results.

[0049]

[Table 3]

TEMP. (°C)	75	60	45	25	5	-15	-20	CODE2	MAX	MIN	EVAL. VALUE
MEAS.VALUE	-1.18	-4.37	-3.52	0.00	2.18	-1.12	-3.26				
1. CALC.VALUE	-1.09	-4.34	-3.58	0.00	2.20	-1.37	-3.66				
DIFFERENCE	-0.09	-0.03	0.06	0.00	-0.02	0.25	0.40	A	0.40	-0.09	0.40
2. CALC.VALUE	-0.65	-4.18	-3.54	0.00	2.22	-1.35	-3.65				
DIFFERENCE	-0.53	-0.19	0.02	0.00	-0.04	0.23	0.39	B	0.39	-0.53	0.53
3. CALC.VALUE	-0.73	-4.20	-3.54	0.00	2.22	-1.33	-3.61				
DIFFERENCE	-0.45	-0.17	0.02	0.00	-0.04	0.21	0.35	C	0.35	-0.45	0.45
4. CALC.VALUE	-0.78	-4.21	-3.55	0.00	2.21	-1.40	-3.73				
DIFFERENCE	-0.40	-0.16	0.03	0.00	-0.03	0.28	0.47	D	0.47	-0.40	0.47
5. CALC.VALUE	-0.85	-4.23	-3.55	0.00	2.22	-1.38	-3.69				
DIFFERENCE	-0.33	-0.14	0.03	0.00	-0.04	0.26	0.43	E	0.43	-0.33	0.43
6. CALC.VALUE	-1.03	-4.31	-3.57	0.00	2.24	-1.16	-3.38				
DIFFERENCE	-0.15	-0.06	0.05	0.00	-0.06	0.04	0.12	F	0.12	-0.15	0.15
7. CALC.VALUE	-1.10	-4.33	-3.57	0.00	2.24	-1.14	-3.34				
DIFFERENCE	-0.08	-0.04	0.05	0.00	-0.06	0.02	0.08	G	0.08	-0.08	0.08
8. CALC.VALUE	-1.15	-4.34	-3.57	0.00	2.24	-1.21	-3.46				
DIFFERENCE	-0.03	-0.03	0.05	0.00	-0.06	0.09	0.20	H	0.20	-0.06	0.20
9. CALC.VALUE	-1.23	-4.36	-3.57	0.00	2.24	-1.19	-3.42				
DIFFERENCE	0.05	-0.01	0.05	0.00	-0.06	0.07	0.16	J	0.16	-0.06	0.16
10. CALC.VALUE	-0.95	-4.33	-3.59	0.00	2.17	-1.55	-3.90				
DIFFERENCE	-0.23	-0.04	0.07	0.00	0.01	0.43	0.64	K	0.64	-0.23	0.64
11. CALC.VALUE	-1.03	-4.34	-3.59	0.00	2.17	-1.52	-3.85				
DIFFERENCE	-0.15	-0.03	0.07	0.00	0.01	0.40	0.59	L	0.59	-0.15	0.59
12. CALC.VALUE	-1.08	-4.36	-3.59	0.00	2.17	-1.60	-3.98				
DIFFERENCE	-0.10	-0.01	0.07	0.00	0.01	0.48	0.72	M	0.72	-0.10	0.72
13. CALC.VALUE	-1.15	-4.37	-3.59	0.00	2.17	-1.57	-3.93				
DIFFERENCE	-0.03	0.00	0.07	0.00	0.01	0.45	0.67	N	0.67	-0.03	0.67
14. CALC.VALUE	-1.33	-4.46	-3.61	0.00	2.19	-1.35	-3.62				
DIFFERENCE	0.15	0.09	0.09	0.00	-0.01	0.23	0.36	P	0.36	-0.01	0.36
15. CALC.VALUE	-1.40	-4.47	-3.61	0.00	2.19	-1.33	-3.58				
DIFFERENCE	0.22	0.10	0.09	0.00	-0.01	0.21	0.32	R	0.32	-0.01	0.32
16. CALC.VALUE	-1.45	-4.49	-3.62	0.00	2.19	-1.40	-3.70				
DIFFERENCE	0.27	0.12	0.10	0.00	-0.01	0.28	0.44	T	0.44	-0.01	0.44
17. CALC.VALUE	-1.53	-4.50	-3.62	0.00	2.19	-1.38	-3.66				
DIFFERENCE	0.35	0.13	0.10	0.00	-0.01	0.26	0.40	W	0.40	-0.01	0.40

[0050]

For each candidate, a calculated value - a measured value = a difference in plus-side maximum value (MAX) or a difference in minus-side maximum value (maximum absolute value: MIN) are obtained, and by comparing the absolute values of those maximum values, the value larger in absolute value is found as an evaluated value. Fig. 3 shows a maximum value and a evaluated value together for each candidate. Out of the candidates, a candidate that has the smallest evaluated value, in other words, a candidate with a calculation result most approximate to the measured value is selected, and the indication code allocated to the selected candidate is decided to be the second indication code. Among those shown in Table 3, the code "G" allocated to a candidate with the smallest evaluation value of "0.08" is decided to be the second indication code.

[0051]

(Indication Process)

Thus, by combining a first indication code expressed by two letters with a second indication code expressed by one letter, in other words, by placing a second indication code after a first indication code, a 3-letter temperature characteristic code can be obtained. This temperature characteristic code is printed on the surface of a crystal resonator. To take a case in Table 3 as an example, because

a measured value of frequency deviation in the atmosphere at 75℃ is -1.18 (about -1.2), the first indication code is decided to be "5X" from Table 1, and the second indication code is decided to be "G" as described above. Therefore, as a three-letter temperature characteristic code, "5XG" is obtained, and this temperature characteristic code is printed on the surface of the crystal resonator.

[0052]

Fig. 8 is a plan view of a crystal resonator C on which this temperature characteristic code is printed. A region α in this figure is a region where the three-letter temperature characteristic code is printed.

[0053]

A region β in Fig. 8 is a region where the above-mentioned two-dimensional data code is displayed. More specifically, in this region β, a number of dots are so formed by a laser that, by reading the formed positions of the dots, information about each coefficient can be obtained.

[0054]

- A Case of Experiment -

Description will be made of a case of experiment conducted to confirm the high approximation accuracy of an approximate equation formed by coefficients in a temperature characteristic code indicated on the crystal resonator as described above.

[0055]

In this experiment, a measured value and a calculated value of frequency deviation were obtained on each of a plurality of crystal resonators (1000 pieces for example) every 5 degrees in a range of environmental temperatures of 75℃ to -20℃, and an average value Xber of differences between the above-mentioned two values, variations δ of measured values, a plus-side maximum value (MAX) and a minus-side maximum value (MIN) in differences of measured values against calculated values were obtained. The results are shown in Table 4 for example.

[0056]

[Table 4]

TEMP.	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20
Xber	0.00	0.01	0.00	0.00	0.00	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
σ	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.00	0.04	0.05	0.05	0.06	0.06	0.05	0.05	0.05	0.07
MAX	0.26	0.27	0.19	0.18	0.20	0.20	0.17	0.18	0.18	0.10	0.00	0.14	0.15	0.16	0.19	0.19	0.22	0.23	0.07	0.26
MIN	-0.14	-0.13	-0.18	-0.14	-0.17	-0.19	-0.27	-0.19	-0.14	-0.11	0.00	-0.16	-0.14	-0.19	-0.19	-0.26	-0.21	-0.15	-0.13	-0.18

[0057]

As shown in Table 4, the average values and variations are reduced to very low levels of value, and also, absolute values of differences between measured values against calculated values are reduced to 0.3ppm or less, which are required when they are applied to a digital temperature-compensated crystal oscillator, and therefore it is known that indication codes are indicated which make it possible to find coefficients by which to obtain an approximate equation with extremely high approximation accuracy.

[0058]

- Description of a Production System -

Next, description will be made of a production system of crystal resonators carrying on their surface a three-letter temperature characteristic code and a two-dimensional data code as described above. This system is intended to make it possible to obtain an approximate equation by recognizing the above-described coefficients by using the temperature characteristic codes or two-dimensional data codes and prepare data for temperature compensation.

[0059]

As shown in Fig. 9, this line includes a main transfer line L1 for transferring crystal resonators C, C ..., and a reader 2 as means to read codes and a discriminating portion 3 as means

to discriminate parts arranged in this order from the upstream side (left side in the figure) down on the main transfer line L1, and the discriminating portion 3 is connected to an extension line L2 coupled to an indication code scanning station 4.

[0060]

The reader 2 includes a camera 21 and an image processing portion 22 to process image information from the camera 21. The camera 21 takes a picture of the two-dimensional data code on a crystal resonator C, and the image information is transmitted to the image processing portion 22. The image processing portion recognizes the formed positions of dots of the two-dimensional data code based on image information from the camera 21, and thereby reads information about each coefficient. From information about the coefficients read by the image processing portion 22, an approximate equation of the temperature characteristic of the crystal resonator C is obtained, and from this approximate equation, data for temperature compensation is acquired.

[0061]

The image processing portion 22 is connected to the decision portion 23 as means to decide whether or not information of each coefficient has been read satisfactorily. It is arranged that a decision signal at the decision portion 23 is sent to the

discriminating portion 3. In response to the decision signal, the discriminating portion 3 switches between transferring a crystal resonator C to the subsequent process of the main transfer line L1 or ejecting the crystal resonator C to an extension line L2. More specifically, when information about each coefficient has been read satisfactorily by the image processing portion 22, the crystal resonator C is transferred to the subsequent process of the main transfer line L1, or when information about each coefficient could not be read satisfactorily by the image processing portion 22, the crystal resonator C is ejected onto the extension line L2.

[0062]

The extension line L2 is connected to the above-mentioned indication code scanning station 4 for the worker to visually check a 3-digit temperature characteristic code on the crystal resonator C. In other words, the worker visually checks the crystal resonator C ejected onto the extension line L2 with a magnifying glass, for example, at the indication code scanning station 4, and he inputs the information into an input device 41 at this station 4 to put the crystal resonator C back onto the main transfer line L1. For example, the crystal resonator C is put back on the main transfer line L1 by using a return line L3 shown with imaginary lines in Fig. 9. Thus, even for a crystal resonator C on which the dot-formed positions of the

two-dimensional data code could not be recognized, an approximate equation of a temperature characteristic can be obtained because the worker visually checks the 3-digit temperature compensation code and inputs information at the indication code scanning station, and from this approximate equation, it is possible to create data for temperature compensation.

[0064]

- Effect of the Embodiment -

As has been described, according to this embodiment, because information about a plurality of coefficients in an approximate equation, representing the temperature characteristic of a crystal resonator, is coded in digits or alphabetical letters, it is possible to provide information about coefficients visually recognizable by the worker. In the past, information about coefficients was obtained only by two-dimensional data code, and if there were scars or traces of surface processing in the indication area, there was a possibility that the camera was unable to sense the dot-formed positions. In this mode of embodiment, temperature characteristic codes in the form visually recognizable to the worker are used and therefore information about coefficients can be obtained securely and approximate equation information in a cubic curve can be obtained correctly.

[0064]

- Other Modes of Embodiment -

In the above-described mode of embodiment, in the first-indication-code deciding process, deviations of oscillation frequency of a crystal resonator in the atmosphere at 75℃ have been measured, but the present invention is not limited to this temperature and it is possible to perform a first-indication-code deciding process at any optional temperature.

[0065]

In the first-indication-code deciding process, first indication codes have been decided based on correlation between frequency deviations and linear coefficients a1, but in the present invention, first indication codes may be decided based on correlation between frequency deviations and coefficients other than the linear coefficients a1.

[0066]

Furthermore, in the second-indication-code deciding process, combinations of coefficients in checking correlation are not limited to those combinations described above. When obtaining second indication codes indicating correlations, it is possible to adopt combinations between any optional coefficients, such as a correlation between the linear coefficient a1 and the second order coefficient a2, a

correlation between the second order coefficient a2 and the cubic coefficient a3, a correlation between the linear coefficient a1 and the fourth order coefficient a4, and a correlation between the cubic coefficient a3 and the fifth order coefficient a5, for example.

[0067]

Moreover, a plurality of candidates for correlation in the second-indication-code deciding process are not limited to 17 as mentioned above, but it is possible to set any number of candidates. However, if the number of candidates is reduced, there is a possibility that the approximation accuracy will go down. On the other hand, if the number of candidates is increased, the calculation process takes a long time or the number of digits or letters of a code must be increased as the number of second indication codes is increased. For this reason, it is necessary to set an appropriate number of candidates.

[0068]

In the above-described mode of embodiment, a three-letter temperature characteristic code and a two-dimensional data code are written together, but a temperature characteristic code may only be indicated on a crystal resonator.

[0069]

[Effect of the Invention]

As is clear from the above description, in the present

invention, by adopting codes clearly visible to the worker to show information about a plurality of coefficients of an approximate equation, information about all coefficients can be discerned securely. With conventional electronic parts carrying only a two-dimensional data code, if the two-dimensional data code could not be read with the camera, there is no more means left to obtain coefficient information, and they are scrapped. In contrast, according to the present invention, information about all coefficients can be obtained by visually discerning the temperature characteristic codes, eliminating wasteful abandoning of electronic part, improving the yield rate of electronic parts, and reducing production cost.

[0070]

Supposing that second indication codes are formed by associating correlations between a specific coefficient and other coefficients with correlations between a plurality of coefficients other than the specific coefficient, even if a high-order approximate equation is adopted, it is possible to use code indication without increasing the number of code letters too much, it is possible to indicate information capable of providing a high approximation accuracy in a relatively small indication area, and it is also possible to improve the usefulness of the method showing temperature characteristic

codes.

[0071]

Indication codes are formed such that a plurality of candidates are set for correlations between a specific coefficient and other coefficients, a plurality of candidates are set for correlations between a plurality of coefficients other than the specific coefficient, an indication a code is allocated to each of candidates, and out of those candidates, an indication code allocated to a candidate which makes it possible to provide an approximate equation having highest approximation accuracy is decided to be a second indication code. In this case, even if errors occur in obtaining a correlation between coefficients, it becomes possible to find a correlation between coefficients, which is almost unsusceptible to effects of errors. Consequently, approximation accuracy can be made still higher.

[0072]

Furthermore, when it is arranged that a two-dimensional data code and a temperature characteristic code are written together, even if the two-dimensional data code could not be read by the image pickup means, it is possible to obtain information about each coefficient by visually recognizing the temperature characteristic code. Therefore, it is possible to coefficient information from substantially all electronic

parts.

[Brief Description of the Drawings]

Fig. 1 is a block diagram showing a circuit configuration of a digital temperature-compensated crystal oscillator according to a mode of embodiment of the invention;

Fig. 2 is a graph showing a correlation between frequency deviations and the linear coefficient a1 when a plurality of crystal resonators are excited in the atmosphere at 75℃;

Fig. 3 is a graph showing a correlation between the linear coefficient a1 and the second order coefficient a2;

Fig. 4 is a graph showing a correlation between the linear coefficient a1 and the cubic coefficient a3;

Fig. 5 is a graph showing a correlation between the second order coefficient a2 and the fourth order coefficient a4;

Fig. 6 is a graph showing a correlation between the cubic coefficient a3 and the fifth order coefficient a5;

Fig. 7 is a diagram showing an example of an approximated curve obtained by each candidate of a correlation between coefficients;

Fig. 8 is a plan view of a crystal resonator;

Fig. 9 is a plan view showing a part of a production system of crystal resonators; and

Fig. 10 is a diagram showing the relation between frequency deviation and temperature in an AT-cut crystal resonator.

[Description of Symbols]

2 ... Reader (Means to read codes)

23 ... Deciding portion (Deciding means)

3 ... Discriminating portion (Means to discriminate parts)

4 ... Indication code scanning station

L1 ... Main transfer line (Production line)

C ... Crystal resonator (Electronic part)

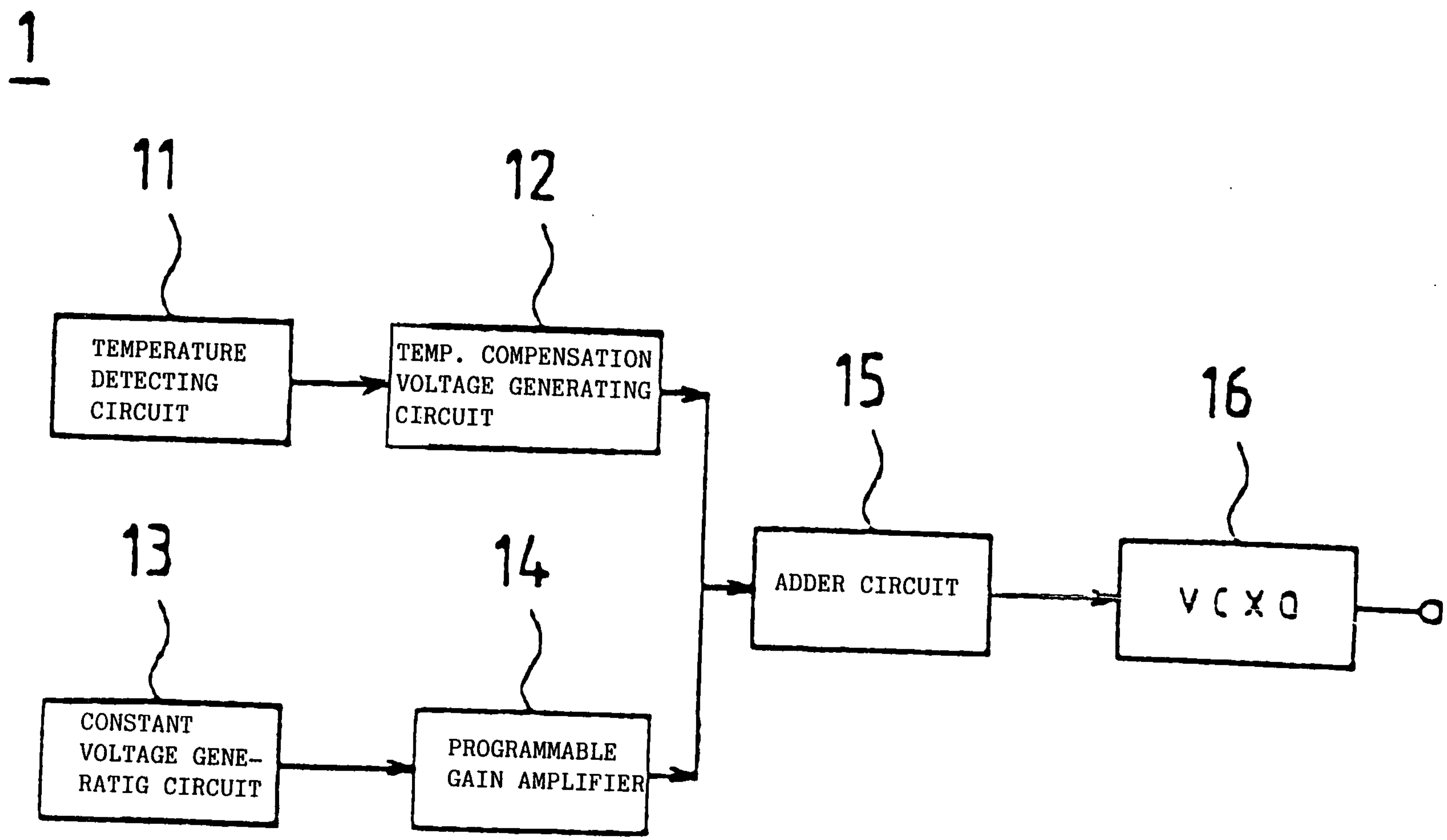
1
11
12
TEMPERATURE DETECTING CIRCUIT
TEMP. COMPENSATION VOLTAGE GENERATING CIRCUIT
15
16
13
14
ADDER CIRCUIT
VCXO
CONSTANT VOLTAGE GENE-RATIG CIRCUIT
PROGRAMMABLE GAIN AMPLIFIER

FIG. 2

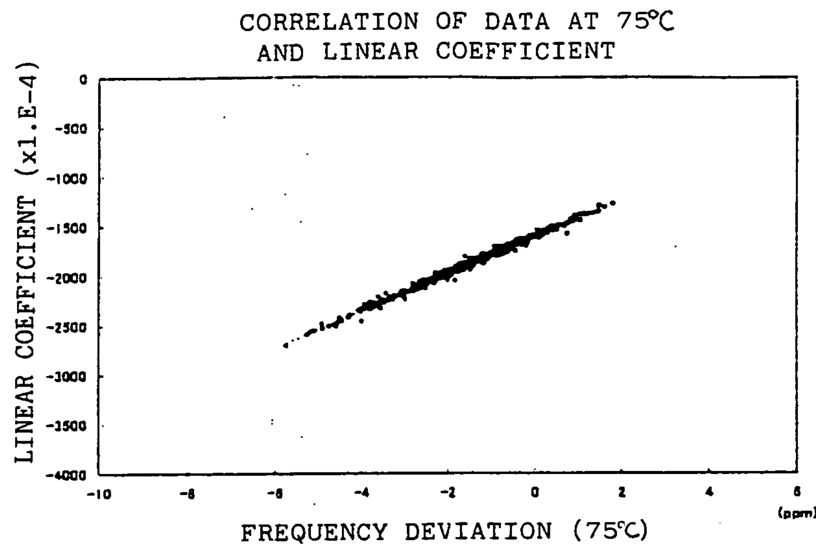
CORRELATION OF DATA AT 75°C
AND LINEAR COEFFICIENT
LINEAR COEFFICIENT (x1.E-4)
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-10
-8
-6
-4
-2
0
2
4
6
(ppm)
FREQUENCY DEVIATION (75°C)

FIG. 3

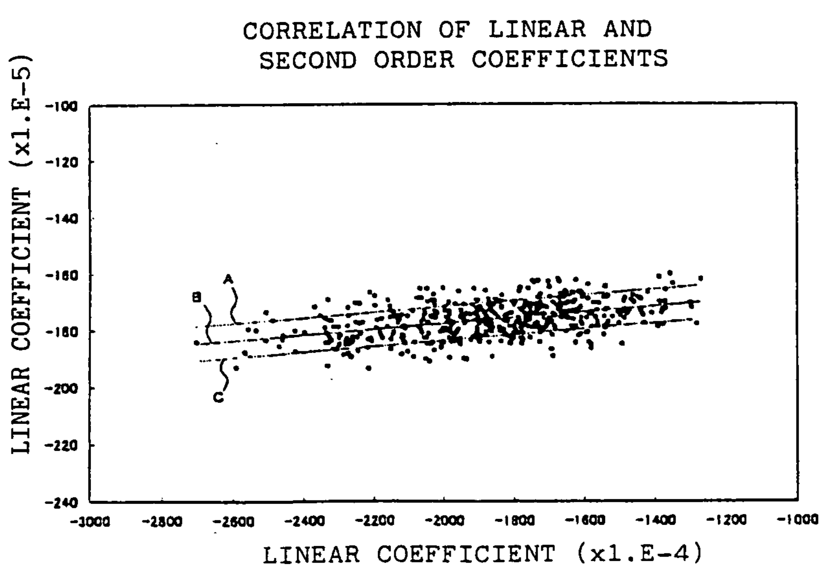
CORRELATION OF LINEAR AND
SECOND ORDER COEFFICIENTS
LINEAR COEFFICIENT (x1.E-5)
-100
-120
-140
-160
-180
-200
-220
-240
A
B
C
-3000
-2800
-2600
-2400
-2200
-2000
-1800
-1600
-1400
-1200
-1000
LINEAR COEFFICIENT (x1.E-4)

FIG. 4

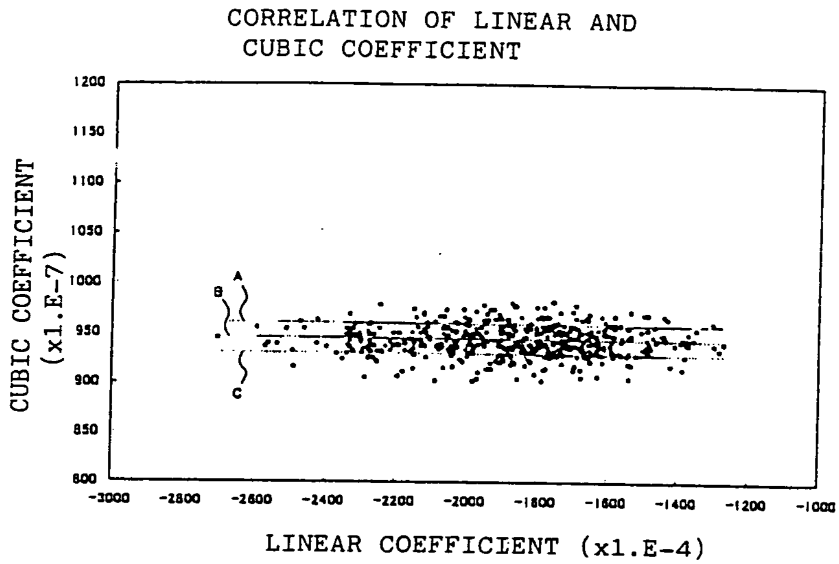
CORRELATION OF LINEAR AND
CUBIC COEFFICIENT
CUBIC COEFFICIENT
(x1.E-7)
1200
1150
1100
1050
1000
950
900
850
800
A
B
C
-3000
-2800
-2600
-2400
-2200
-2000
-1800
-1600
-1400
-1200
-1000
LINEAR COEFFICIENT (x1.E-4)

FIG. 5

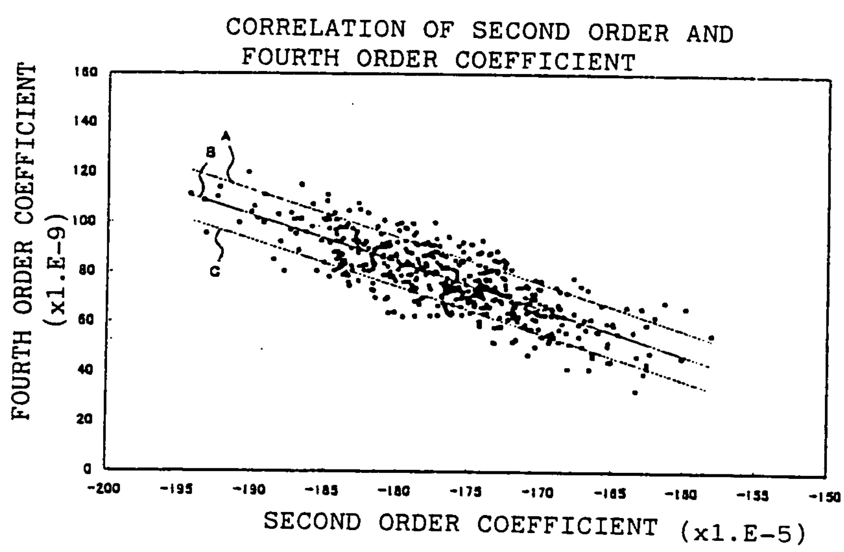
CORRELATION OF SECOND ORDER AND
FOURTH ORDER COEFFICIENT
FOURTH ORDER COEFFICIENT
(x1.E-9)
160
140
120
100
80
60
40
20
0
A
B
C
-200
-195
-190
-185
-180
-175
-170
-165
-160
-155
-150
SECOND ORDER COEFFICIENT (x1.E-5)

FIG. 6

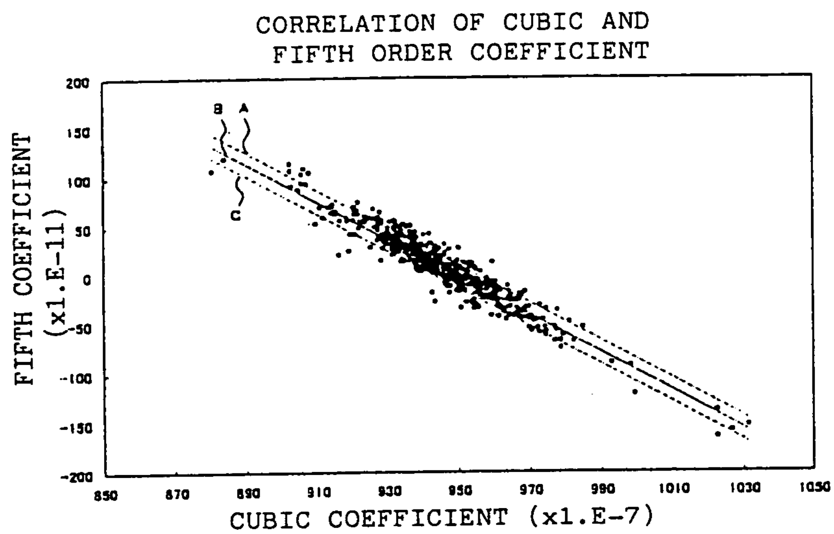
CORRELATION OF CUBIC AND
FIFTH ORDER COEFFICIENT
FIFTH COEFFICIENT
(x1.E-11)
200
150
100
50
0
-50
-100
-150
-200
B
A
C
850
870
890
910
930
950
970
990
1010
1030
1050
CUBIC COEFFICIENT (x1.E-7)

FIG. 7

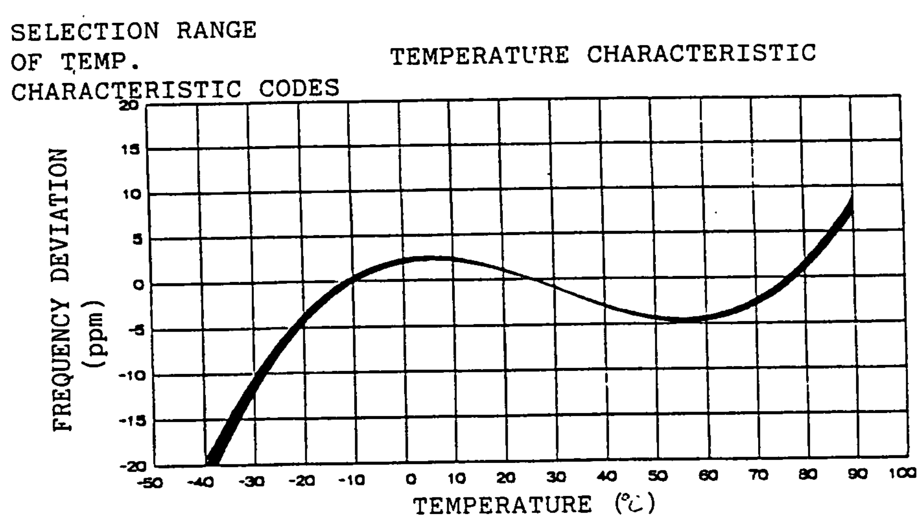
SELECTION RANGE
OF TEMP.
CHARACTERISTIC CODES
TEMPERATURE CHARACTERISTIC
FREQUENCY DEVIATION
(ppm)
20
15
10
5
0
-5
-10
-15
-20
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
TEMPERATURE (°C)

FIG. 8

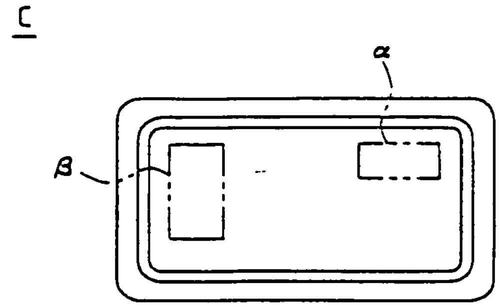

FIG. 9

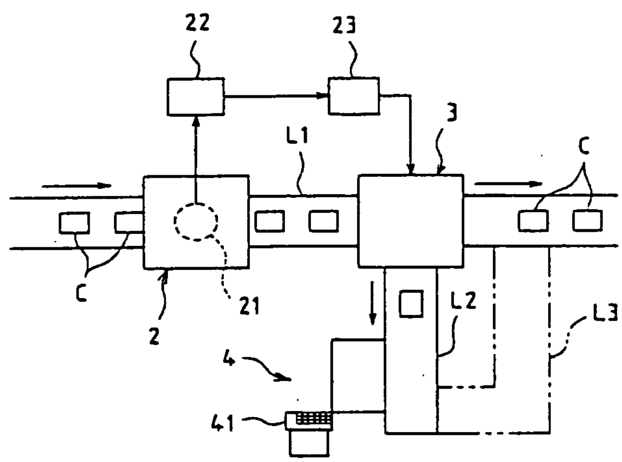

FIG. 10